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On the Efficiency of Introduction of American Insects Feeding on the Common Ragweed (*Ambrosia artemisiifolia* L.) in the South of Russia

O. V. Kovalev[a], Yu. V. Tyutyunov[b,c], L. P. Iljina[b], and S. V. Berdnikov[d]

[a]*Zoological Institute of Russian Academy of Sciences, St. Petersburg, 199034 Russia*
e-mail: kovalev@OK11495.spb.edu
[b]*Institute of Arid Zones, Southern Scientific Center of Russian Academy of Sciences, Rostov-on-Don, Russia*
[c]*Research Institute of Mechanics and Applied Mathematics, Southern Federal University, Rostov-on-Don, Russia*
e-mail: tyutyunov@sfedu.ru; iljina@ssc-ras.ru
[d]*Southern Scientific Center of Russian Academy of Sciences, Rostov-on-Don, Russia*
e-mail: berdnikov@ssc-ras.ru

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Abstract—The explosive spread of the common ragweed induced by disturbance of the natural habitats in the postwar years created an ideal vacant niche for acclimation of North American phytophagous insects introduced to the South of Russia in the 1960–70s. The propagation of these species resulted in restoration of natural succession periodicity and promoted the subsequent acclimation of the predatory stink bug *Perillus bioculatus*, an extremely important agent of biological control of the Colorado potato beetle. Besides the economic effect, the studies of these introduction events were significant from the theoretical viewpoint, revealing the phenomenon of a solitary population wave (SPW) of the ragweed leaf beetle. The theoretical concept of an SPW as the key factor of efficiency of the biological control of weeds underlies the method of suppression of the common ragweed which consists in inducing SPWs by establishing local refuges for the initial buildup of the beetle population.

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Invasions of alien plants belong to the most important factors in the anthropogenic evolution of vegetation. The attention of European and Russian researchers is currently focused on the growing activity of invasive North American Compositae of the genera *Ambrosia*, *Xanthium*, *Cyclachaena*, etc. These highly competitive species not only disperse in disturbed anthropogenic communities but also occupy the dominant positions in phytocenoses and replace other species via successful competition for space and nutrients. Of them, ragweeds of the genus *Ambrosia* pose the greatest threat (Vinogradova et al., 2010; Mirkin and Naumova, 2012). The common ragweed *A. artemisiifolia* L. is a quarantine weed which has been actively expanding its range in the Eastern and Western Europe during the recent years (Gladieux et al., 2011).

The successful control of the common ragweed requires an unbiased assessment of the present state of events and the results of the previous actions aimed at suppressing this invasive and allergy-inducing weed. Without such an assessment, it would be impossible to determine the current priorities of biological control, which differ considerably from those of the last decades, and to select the most efficient ways of their accomplishment.

The history of invasion of the common ragweed in Russia can be clearly subdivided into three phases: the initial phase (1918–1942) of explerent expansion of this weed which easily occupied vacant territories but did not have any deleterious effect on the ecosystems; the post-war phase (the 1940–70s) of an "ecological explosion" of the common ragweed caused by damage to soils as the result of military activities and development of dense and homogenous phytocenoses which resisted succession for many years; the modern phase, resulting from the spread of the first beneficial alien phytophagous insects: the olive-shaded bird dropping moth *Tarachidia candefacta* Hübn. (Lepidoptera, Noctuidae) and the ragweed leaf beetle *Zygogramma suturalis* F. (Coleoptera, Chrysomelidae), which were introduced in European Russia in the 1960–70s (Kovalev, 1971; Kovalev and Medvedev, 1983). After prolonged tests for specificity, these two species were initially introduced in the North Caucasus and then dispersed far beyond the limits of the South of Russia. The research related to the acclimation of ragweed phytophages resulted in the discovery of a very important phenomenon of solitary population waves (SPWs) (Kovalev and Vechernin, 1986; 1989), which represent the key factor of efficiency of biological control of the common ragweed (Kovalev, 1989c, 2004b). Although all the practical measures of biological control were stopped by the early 1990s, the effects of population processes related to the ragweed leaf beetle SPW can be observed in various agrocenoses even 20 years later.

The Solitary Population Wave as a Factor Determining the Efficiency of Biological Control

The SPW of the ragweed leaf beetle is characterized by unusually high concentrations of insects within a narrow front, reaching 5000 ind./m^2. A wave front 1.5 km long passing through a sainfoin field (80 ha) included about 10 million beetles. The advance rate of the wave reached 3 m/day. As the wave moved across the field, the territory behind it was completely free or the ragweed (Figs. 1–3). Analysis of soil infestation in a territory inhabited by the ragweed leaf beetle (the environs of Stavropol) also showed an abrupt decrease in the amount of ragweed seeds (Kovalev, 1989a): for example, the density of ragweed seeds in the surface soil layer dropped from 24 000 per 1 m^2 in 1980 to 35 per 1 m^2 in 1985.

A similar process of an "ecological explosion" of the Eurasian St John's wort *Hypericum perforatum* L. (Clusiaceae) took place in North America (Huffaker, 1967). It is well known that the avalanche-like population growth of this invasive plant was stopped after successful introduction of several species of leaf beetles of the genus *Chrysolina* Motsch. (Coleoptera, Chrysomelidae) from Europe (Julien and Griffiths, 1998). Unfortunately, no experts in phytocenology took part in estimating the economic importance of suppression of this adventive weed, whereas entomologists did not pay attention to the manifestations of solitary population waves of the introduced phytophages.

Further analysis of the worldwide experience of biological control (Kovalev, 2004b; Moran et al., 2009) showed that the efficiency of the most successful campaigns of biological weed suppression was determined by SPWs. In particular, in 1940–1950 the European leaf beetle *Chrysolina quadrigemina* (Suffrian) destroyed the American foci of the invasive St John's wort, from Canada in the north to Chile and Argentine in the south, reducing the density of this weed by 99% and providing the means of its persistent and prolonged control (Julien and Griffiths, 1998). Equally efficient was the SPW of the South American salvinia weevil *Cyrtobagous salviniae* Calder et Sands (Curculionidae), which was introduced into the freshwater reservoirs of Australia, Africa, India, and Oceania and successfully suppressed the kariba weed *Salvinia molesta* Mitchell (Salviniaceae) (Room and Thomas, 1985; Room, 1990). However, although the wave properties of dispersal of these phytophages were noted by the authors of all the cited publications, the significance of the solitary population waves was overlooked by entomologists, and such waves were not considered as a separate factor of efficiency of the biological method (Kovalev, 2004b). Kovalev and Vechernin (1986, 1989) were the first to discuss the conditions of the phytophage population wave induction as the basis of efficient biological control and to propose a mathematical model of formation and advance of the SPW of the ragweed leaf beetle. This model was included in the *Manual of Physical and Mathematical Model Analysis of Ecosystems* (Alekseev et al., 1992); its universality was confirmed by successful practical use of the model to describe the population wave of the northern tamarisk beetle *Diorhabda carinulata* (Desbrochers) (Chrysomelidae) during introduction of the species in the west of the US (Moran et al., 2009). Theoretical results confirming the key role of spatial wave patterns in achieving efficient biological control in the trophic system were independently obtained by Tyutyunov and co-authors (Govorukhin et al., 2000; Tyutyunov et al., 2002; Sapoukhina et al., 2003). The influence on the biological control efficiency of such factors as spatial heterogeneity and the ability of the control agents to move towards the areas of food concentration and to aggregate in them was considered from the theoretical standpoint by many researchers (Lewis, 1994; Kareiva and Odell, 1987; Grünbaum, 1998; Okubo and Levin, 2001; Fagan et al., 2002, etc.). However, the particular significance of the results of introduction and acclimation of the ragweed leaf beetle in Stavropol Territory (Kovalev and Vechernin, 1986; 1989; *Theoretical Foundations…*, 1989), and later in Abkhazia (unpublished data of O.V. Kovalev), is determined by the fact that the theoretically predicted SPW efficiency was confirmed by the results of large-scale field application.

Fig. 1. Ragweed leaf beetles *Zygogramma suturalis* F. in a solitary population wave on damaged common ragweed plants (Stavropol Territory). Photo by O.V. Kovalev.

What are the conditions of development of an SPW? First of all, it should be noted that solitary population waves cannot be formed within the primary range of a species. However, even among introduced species, only a few reveal the ability to form the SPW; until recently, no such waves were observed in European Russia for any of the hundreds of introduced species. The behavior of insects forming SPWs when introduced into terrestrial or freshwater ecosystems follows the same scenario. The insects do not (or cannot) move out of such unusual aggregations as the wave advances leaving behind a territory with totally depleted trophic resources. The formation and movement of such a wave is a systemic effect that manifests itself at the population level: each individual of the phytophage tends to avoid aggregations with insufficient trophic resources, and this individual behavior determines self-organization of the population wave (Tyutyunov et al., 2010).

The successful campaigns of biological weed control on different continents were typically characterized by rapid growth of the agent population: during the formation of the SPW, tens of millions of individuals are amassed within 4–6 generations (Room and Thomas, 1985; Kovalev, 2004b). The necessary condition for such growth is the presence of sufficiently large uniform territories with high densities of the host plant. The disturbed soil cover is regarded as the most important factor facilitating establishment of the common ragweed within its potential range (MacDonald and Kotanen, 2010); correspondingly, after the World War II, dense foci of this weed rapidly occupied the habitats disturbed as the result of military activity. The history of military activities (Matishov et al., 2012), rather than genetic or phytocenological factors, seem to be the key to the problem addressed by the Western researcher (Gladieux et al., 2011): why did the common ragweed spread faster and more successfully in Russia than in Western Europe even though it appeared in Russia several centuries later. The common ragweed invasion during the postwar period could be described as an "ecological explosion" (Kovalev, 1989a): this species became the prevalent landscape weed in the agricultural zone of the North

Fig. 2. Flying adults of *Zygogramma suturalis* F. in a solitary population wave (Stavropol Territory). Photo by O.V. Kovalev.

Caucasus. The ragweed blocked the natural succession processes and often remained the only component of vegetation, reaching a canopy density of 7 000 shoots per 1 m^2, a seed density of 20–30 000 seeds per 1 m^2 of the surface soil layer, and a phytomass of 10 tons/ha. Such values may seem impossible today, but they existed in the 1980s and facilitated the development of the SPW of the ragweed leaf beetle.

It follows from the mathematical model of Kovalev and Vechernin (1989) that the formation of the SPW of the ragweed leaf beetle advancing with velocity V through a plant association containing the common ragweed requires a certain density of beetles per length unit of the wave front. The required density N can be estimated by the formula (see Kovalev and Vechernin, 1989: p. 117):

$$N = \rho V / A,$$

where ρ is the ragweed phytomass density and A is the intensity of ragweed consumption by one beetle. For example, substituting the values $\rho = 200$ g/m^2, $A = 0.024$ g/day, and $V = 0.5$ m/day, the density required for the SPW development can be determined as $N = 4200$ beetles per 1 m of the wave front. If the density of the beetles has not yet reached (or cannot reach) such a great value, the advance rate of the wave will be lower. For example, at $N = 1000$ beetles per 1 m of the wave front and at the same density of the ragweed, the advance rate of the wave is only 0.1 m/day. Since the width of the wave may reach 4–5 m under the natural conditions (Kovalev, 1989c; Kovalev and Vechernin, 1989), the wave would not appear to be moving in this case. It is clear that a SPW can be considered only if the daily distance traveled by the wave (V) is comparable with its width (L).

The territory occupied by the ragweed leaf beetle started to expand only after the beetle density exceeded the critical value ensuring elimination of the weed, i.e., after the formation of a SPW. Introduction of only 1500 beetles from Canada into Stavropol Ter-

Figs. 3. Overwintered adults of *Zygogramma suturalis* F. on common ragweed shoots (Stavropol Territory). Photo by O.V. Kovalev.

ritory in 1978 resulted in the following dynamics of its expansion (Fig. 4): 200 ha in 1981, 20 000 ha in 1984, and 300 000 ha in 1986. The following additional yields were observed in 1985 in the agricultural lands of the Pelagiadskii state farm (Stavropol Territory) with a total area of 709 ha, completely cleared of the common ragweed: 13 tons/ha of alfalfa, 6.4 tons/ha of sainfoin, and 9.6 tons/ha of maize green mass. The advance rate of the SPW in 1985 reached 3 m/day; the formation and merging of secondary foci of the phytophage resulted in its rapid expansion over the main zones of intensive agriculture in the North Caucasus in 1987–1988. Due to their high resistance to land treatment in the crop rotation systems, the beetles drastically reduced the amount of weed seeds stored in the soil. The expansion of the leaf beetle onto the wastelands overgrown with ragweed restored the natural succession processes which used to be typical of these territories before the ragweed invasion (Kovalev and Vechernin, 1989). The most spectacular result was obtained in the crop rotation systems, where the common ragweed can still be found only on the periphery of the fields.

It is essential that within its original North American range, the ragweed leaf beetle forms no aggregations and is characterized by very low population densities (Kovalev, 1989b, 2004b). Therefore, SPWs of

Fig. 3. (Contd.)

this phytophage in the ragweed foci should be created artificially. For this purpose, reserve areas of 2–4 ha with a high density of the ragweed phytomass should be allocated, which should be left untreated for 2–3 years to allow the buildup of the reserve population of the leaf beetle (Cherkashin, 1985; Kovalev and Vechernin, 1989). The efforts aimed at inducing the SPW cannot be considered too costly as compared to its economic benefits (Kovalev, 1989a), since the acclimated phytophage can now be quite easily collected in the territory of Russia. The creation of such reserve areas, serving as centers of origin of the SPWs, in each administrative district infested with the common ragweed was recommended by the experts of the Zoological Institute of the Russian Academy of Sciences (ZIN) and the Stavropol Research Institute of Agriculture in the 1980s.

Specific Traits of the Present-day Control of the Common Ragweed

Unfortunately, funding of the permanent research expedition of the Zoological Institute was stopped at the end of the 1980s, after which not only the practical recommendations but even the theoretical conclusions concerning the importance of SPWs were forgotten. No proper assessment was made of the role of the leaf beetle SPW in the total increase of agricultural crop yield observed at that time; even though considerable extra yields were recorded locally in the fields of the Pelagiadskii state farm in 1985, the farm manager attributed it to the advantages of the team contract system which was then being introduced in agriculture.

Recently, the role of the ragweed leaf beetle was interpreted in quite an unexpected way by Reznik (2009, 2011), who carried out entomological surveys in Stavropol and Krasnodar Territories and in Rostov Province in 2005–2007, i.e., 20 years (!) after the SPW, and considered the efficiency of this phytophage to be “negligibly small” without even mentioning the SPW and the relevant research carried out in these territories decades before (Reznik, 2009). According to the mathematical model, the SPW of the leaf beetle resembles a combustion wave: as the SPW moves, the

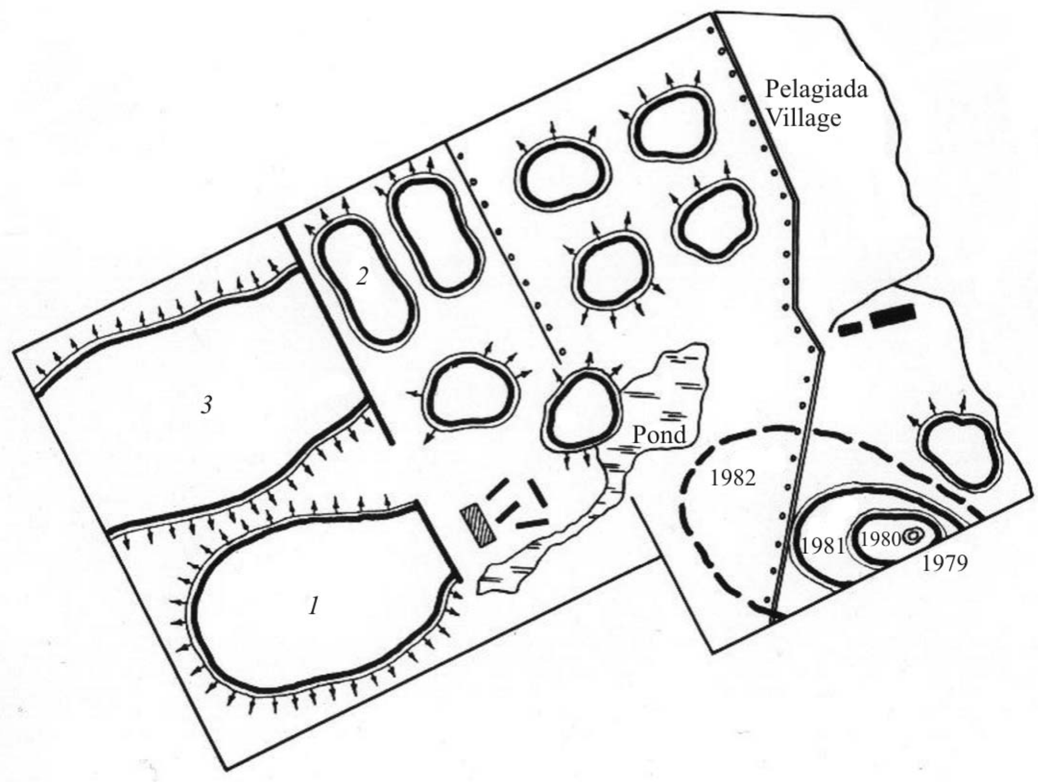

Fig. 4. Formation of solitary population waves of the ragweed leaf beetle in 1983 within the territory colonized by the phytophage in 1978 (environs of Stavropol). *1–3*, fields of maize and perennial grasses.

environment is changed irreversibly since the food plant is destroyed (Kovalev and Vechernin, 1989). If a certain amount of ragweed seeds is preserved in the soil, the SPW can pass repeatedly until these reserves are depleted to a minimum and natural succession is restored in the territories previously occupied by compete patches of ragweed. In view of this, the above interpretation of the processes which were completed many years ago should be considered incorrect.

Suppression of the weed biomass by the SPW of the phytophage removes the inhibitor species blocking the natural succession in the phytocenosis (Mirkin and Naumova, 2012). This result is enhanced by further suppression of the common ragweed by the competitor plant species which in this case serve as phytocenotic control agents (Maryushkina, 1986; Dzybov, 2010; Matishov et al., 2011). The efficiency of the competing cultivars is increased manifold due to synergistic interaction with the phytophage population waves. This is one more manifestation of the prolonged systemic effect of the phytophage SPW on the biocenosis.

Besides the qualitative effects of deblocking and acceleration of succession (Kovalev, 2004; Mirkin and Naumova, 2012), similar to that observed during the introduction of *Chrysolina* leaf beetles in the US (Huffaker, 1967; Julien and Griffiths, 1998), the results of acclimation of the ragweed leaf beetle may be characterized by such quantitative parameters as the density of ragweed seeds and shoots in various phytocenoses.

Within the framework of the interdisciplinary project of the Federal Target Program "Research and Pedagogical Cadres for Innovative Russia" (Matishov et al., 2012), soil samples were taken in September–October 2012 in sunflower fields infested with the common ragweed in the environs of Kagalnik (Azov District, Rostov Province), in the coastal area near the Kagalnik field station of the Southern Research Center of the Russian Academy of Sciences, and on Donskoi Island and the nearshore part of Svinoe Girlo (Taganrog Bay). Samples were taken in the existing monitoring plots, from the soil layers of 0–20 cm and 20–50 cm, with the total mass of the mixed sample from each layer reaching 1.0 kg. The ragweed seed reserves were estimated for the plow horizon of 0–20 cm. The results obtained are given in table. According to the five-point qualitative scale (Fesyunov, 1974), most

The density of common ragweed seeds in the upper soil layer (0–20 cm) near Kagalnik Settlement: seeds per 1 m^2

No.	Monitoring area	Time of sampling	
		1st decade of September	3rd decade of October
1	Sunflower field	775	900
2	Periphery of a sunflower field	1100	1550
3	Forest belt near a sunflower field	420	600
4	Sunflower field	850	1375
5	Boundary of a sunflower field	1250	1725
6	Kagalnik Field Station	100	575
7	Donskoi Island	200	375
8	Wasteland near a cemetery	150	450

samples listed in the table corresponded to very weak (below 500 m^{-2}) and weak (500–1500 m^{-2}) infestation of soil with ragweed seeds; the only exception was sample 5 taken in October which revealed a medium level of infestation (1500–5000 m^{-2}). It is characteristic that the maximum density of ragweed seeds was observed on the periphery of the fields. The samples taken in the environs of Kagalnik at the beginning of September contained somewhat less ragweed seeds in the topsoil layer (0–20 cm) than in the deeper horizon (20–50 cm), possibly due to the fact that the autumn of 2012 was warm and relatively dry, so that the seeds of that year had not yet started to shed.

According to our data, the density of ragweed shoots in Azov District (where Kagalnik Settlement is situated) was 251–265 m^{-2} in fallow lands, 65–98 m^{-2} in mustard and winter wheat agrocenoses, and 72–85 m^{-2} in sunflower agrocenoses; these values were several times smaller than those observed in the 1970s (Cherkashin, 1985; Kovalev, 1989a).

The field studies carried out in the Rostovskii Biosphere Reserve (Orlovskii District, Rostov Province) in 2005–2010 on the basis of the Manych field station of the Southern Scientific Center (SSC) of the Russian Academy of Sciences (Matishov et al., 2011) showed the common ragweed to be absent in the Starikovskii and Krasnopartizanskii protected steppe tracts; within the buffer zone, this quarantine weed was found locally, mainly in heavily trampled pastures, along roads, and near sheep yards and settlements.

A somewhat higher level of infestation of phytocenoses was observed on 5–10 September, 2012, during an SSC expedition in the Republic of Adygea (Shapovalov et al., 2012), where relatively stable clumps of the common ragweed gave shelter to the ragweed leaf beetle and the olive-shaded bird dropping moth. The highest density of ragweed seeds was observed in the topsoil (0–20 cm) horizon of soybean and maize fields: 3800 and 5600 m^{-2}, respectively, which corresponded to the medium and strong levels of infestation. In other survey plots (fallow lands, sunflower fields, field margins, and roadsides) the ragweed seed density did not exceed 600–1300 m^{-2}, which corresponded to the medium level of infestation (Fesyunov, 1974). According to the participants of the expedition (Shapovalov et al., 2012), this situation was the result of regular soil disturbance: the farmers in the Republic of Adygea often till the soil trying to bury the weed seeds; however, most of the seeds remain viable for several decades and may germinate after being brought to the surface by the subsequent tillage (*Theoretical Foundations…*, 1989; MacDonald and Kotanen, 2010; Matishov et al., 2011).

Although the observed signs of fundamental changes following the introduction of ragweed phytophages in the ecosystems certainly do not mean that the problem of suppressing this invasive plant in the South of Russia has been solved, they allow one to adjust the current activities in this field. During the decades that passed since the disintegration of the USSR, the structure of agrocenoses has changed, the farming standards have been generally lowered, numerous abandoned fields and disturbed land plots have appeared; it is particularly important that the common ragweed is now spreading over human settlements, where the ragweed leaf beetle cannot form solitary waves because it is regularly eliminated by the quarantine service together with the host plant. The former USSR republics, as well as some countries of Eastern and Western Europe, are facing similar problems (Bohren et al., 2006; Gladieux et al., 2011; Gerber et al., 2011). Exactly in the same way as in the South of Russia after the World War II (Kovalev, 1989a), disturbance of ecosystems during the military activities in the former Yugoslavia has triggered avalanche-like dispersal of the common ragweed over the Balkan Peninsula (Galzina et al., 2010; Šarić et al., 2012). In Russia, new foci of invasion of this weed are formed for different reasons. A typical example is the incredibly fast dispersal of the common ragweed in Sochi as the result of large-scale destruction of forest assemblages during the building of the Olympics venues complex in 2012. Unless emergency measures are taken, the infestation of phytocenoses in this region will certainly aggravate in the coming years. Therefore, establishment of leaf beetle refuges around human settlements is an important task at the present stage of control of this weed. It would be an error to say that the presence of the ragweed leaf beetle in the ecosystem can by itself solve the problem of weed suppression (Kovalev, 1989a; MacDonald and Kotanen, 2010). The well-tested method of application of this control agent (Cherkashin, 1985; Kovalev and Vechernin, 1986, 1989) was based on artificial induction of solitary population waves of the phytophage in the ragweed foci. This method is still valid, despite the pressing need to introduce new species of the already known complex of the common ragweed phytophages (Kovalev, 1989a; Gerber et al., 2011).

The Specific Features of Invasion of Adventive Weeds of the Subtribe Ambrosiinae (Asteraceae, Heliantheae)

The broad distribution and harmfulness of ambrosiine weeds have become a global problem. One of the factors of successful naturalization of these species is biosynthesis of sesquiterpene lactones which act as analogs of the insect juvenile hormone, causing metabolic disorders in non-specialized phytophagous insects feeding on these plants in the invaded territories. However, on the American continent there is a set of specific phytophages associated with each genus of the subtribe Ambrosiinae; some of these phytophages can be used as introduced control agents. In order to select the potentially narrow oligophages, they were experimentally fed on cockleburs of the genus *Xanthium*, originating from primitive ragweeds (Kovalev, 1989a). The evolution of the genus *Xanthium* was accompanied by biosynthesis of xanthanolides, specific sesquiterpene lactones which are absent in *Ambrosia* and which act as juvenoids on the narrow oligophages of ragweeds. For example, they lead to the development of an additional (sixth) larval instar, higher mortality, an abnormal sex ratio, and other effects in the olive-shaded bird dropping moth *T. candefacta*. These abnormalities reflect the high specificity of this oligophage to ragweeds.

A highly unusual phenomenon was observed during acclimation of the ragweed leaf beetle in the North Caucasus: adult beetles in the SPW were feeding on the leaves of the giant sumpweed *Cyclachaena xanthifolia* (Nutt.) Fresen., a species from a genus closely related to *Ambrosia*. Since the giant sumpweed is one of the most aggressive adventive weeds and an incitant of allergies similar to the ambrosia hay fever, it would be desirable to use the ragweed leaf beetle to suppress this weed, too. However, females feeding on the sumpweed reveal egg development arrest due to the protective action of sesquiterpene lactones.

In order to explain the successful expansion of adventive species during biosphere invasions and to assess the specific traits of taxa in the system “adventive plant—phytophage” during the SPW formation, the concept of “expansion of juvenile taxa” was proposed (Kovalev, 2004a). According to this concept, phylogenetically young species, constituting an initial stage in the evolution of supraspecific taxa, quickly fill the available niches during expansion into disrupted ecosystems. In the evolutionary aspect such taxa act as “cenophobes” and often form the initial stages of successions. Preserving the unstable state of their genomes, such taxa easily colonize new territories by invading the disturbed ecosystems. Among angiosperms, the most successful invasive plants and the most harmful weeds are herbaceous apoplastic forms (Gamalei et al., 2005). The juvenile taxa of apoplastic families, in particular composites, preserve the abilities for extensive divergence and can successfully expand their adaptive zones in case of invasion.

In all the known cases, solitary population waves were formed by phytophages of apoplastic plants (Kovalev, 2004b). All the species introduced into the coevolutionary system “plant–phytophage,” in particular, leaf beetles of the subfamilies Chrysomelinae and Galerucinae, belong to juvenile taxa below the subfamily rank.

Finally, one more positive effect of the dispersal of *Z. suturalis* in the 1980s should be mentioned. Due to very high densities of the leaf beetle in the SPWs, the two-spotted stink bug *Perillus bioculatus* F. (Pentatomidae) was successfully acclimated in the South of Russia, whereas earlier (the 1960–1970s) attempts at introducing this American entomophage had failed. It is essential that the increasing abundance of this predatory bug, which is an important factor of regulation of *Z. suturalis*, was not recorded by entomological surveys (Reznik, 2009, 2011); the entomophage was discovered by chance only in 2008, when it became a regular member of the ecosystem (Ismailov and Agas'eva, 2010; Esipenko, 2012). The two-spotted stink bug is perhaps the only promising control agent to be used against the Colorado potato beetle in Europe (Sweetman, 1964; Ismailov and Agas'eva, 2010). However, all the attempts to acclimate this bug in any European country, starting from the 1930s, had been unsuccessful, and findings of this species were only recently reported from the European territory of Turkey in 2003 (Kivan, 2004; Rabitsch, 2008, 2010) and from Bulgaria in 2012 (Simov et al., 2012). There were also some unpublished reports of this bug being found in Greece (Rabitsch, 2008). Although the bugs were feeding on the Colorado potato beetle in all these cases, the cited authors did not regard these findings as confirmation of successful introduction since the bugs were too scarce. The exact sources of invasion were not determined; according to different authors, it could result from either the previous attempts at introducing *P. bioculatus* in the Balkans and the relatively mild recent winters (Simov et al., 2012), or the bugs being inadvertently brought from the US by the NATO aircraft (Kivan, 2004). It is evident that the two-spotted stink bug is now spreading over the expanding ranges of the ragweed leaf beetle and the olive-shaded bird dropping moth in the Black Sea basin. In the previous years, this entomophage could not get acclimated in Europe because the female bugs emerge in spring much earlier than the Colorado potato beetle (Ismailov and Agas'eva, 2010). However, adults of the ragweed leaf beetle, belonging to a closely related genus, emerge simultaneously with the bugs. Later, the diet of the two-spotted stink bug is supplemented with larvae of the olive-shaded bird dropping moth *T. candefacta*, one more introduced beneficial species of American origin.

CONCLUSIONS

(1) Successful introduction of a phytophage results in formation of moving solitary population waves (SPWs), which suppress the foci of adventive weeds at unsurpassed rates. The unusually high densities of insects in the SPW, reaching hundreds of millions of individuals, are never observed within the primary range of the species.

(2) An SPW is a special phenomenon displaying some properties of both an autowave and a true soliton. The behavior of insects in the SPW follows a single scenario based on the principles of spontaneous self-organization of orderly wave structures. It has been found through experience that formation of an SPW requires a certain critical density of insects in the initial focus providing a certain number of individuals per length unit of the wave front; in other words, as in the case of soliton induction, an initial impulse with amplitude exceeding a certain threshold value is needed.

(3) As in the case of an autowave, the moving SPW induces irreversible changes in the medium, leaving behind a territory with almost completely destroyed food resource (the common ragweed). However, since ragweed seeds remain in the soil, the plant appears again in the following year, i.e., the medium is restored. Therefore, the SPW can be repeated until the reserve of ragweed seeds is totally eliminated.

(4) By eliminating the prevalence of the common ragweed, the SPWs of the ragweed leaf beetle exert a systemic action on phytocenoses and ensure prolonged restoration of the natural succession processes.

(5) At the modern stage of the common ragweed control, attention should be focused on adaptation of the already tested methods of inducing the SPWs of the ragweed leaf beetle to the conditions of human settlements, and also on introduction of new species from the already known complex of phytophages.

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